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J. R. KANTOR

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J. R. KANTOR,
Indiana University

It is the thesis of the present paper that the operational principle first formulated for physics can with suitable modification be employed to the psychologist's advantage in clearing up many of his age-old problems. This modification involves the enlargement of the principle to include not only (1) the processes of deriving concepts or meanings, but also (2) the control of observational procedure, and (3) the development of postulates.

Basic to our thesis is the view that when the operational principle is extended to include investigative procedures and postulates, psychology and physics both operate in a single natural continuum, with methods and techniques only so far different as the variant phenomena demand. By adopting this modified operationism psychology can rid itself of those undesirable general ideological and specific investigative presuppositions derived from its dualistic heritage.

OPERATIONISM AS A PRINCIPLE OF PHYSICAL SCIENCE

To define the operational principle we refer to Bridgman's "operational theory of the meaning of concepts" which he regards as essential for the critical appraisal of such developments in physics as relativity and quantum mechanics. Bridgman is impressed with the frequently manifested sharp break between observed phenomena on one side and the physicist's equations on the other. Especially in the recent development of wave mechanics the question has arisen: How connect a scientific construction in terms of probability densities with the concrete events of the physical world? That the question is not wanting in poignancy is reflected in the frank declaration of eminent scientists that the bond between the conceptions of modern physics and the objective physical universe is completely severed.

Here is a crisis in the physical sciences calling loudly for strenuous remedies. Accordingly Bridgman proposes a reconsideration of the nature of physical categories—a reconsideration resulting in the view that scientific concepts should be based upon operations performed by the scientist.

Asserting that the operational principle was inspired by laboratory operations, Bridgman illustrated it by defining length as a magnitude derived from a set of measuring operations. Generalizing, all scientific concepts must be derived from such actual operations.

As Bridgman points out,[1] operational analysis is not only a means of testing terms or concepts but questions also. Doubtless all scientists have implicitly formulated for themselves the idea that the boundary between science and nonscience consists in differentiating between a meaningless and a meaningful problem. In his first Critique Kant vividly characterized this issue when he wrote:

> It is a great and necessary proof of wisdom and sagacity to know what questions may be reasonably asked. For if a question is absurd in itself and calls for an answer where there is no answer, it does not only throw disgrace on the questioner, but often tempts an uncautious listener into absurd answers, thus presenting, as the ancients said, the spectacle of one person milking a he-goat, and of another holding the sieve.[2]

We are reminded here also of G. Cantor's thesis that "in mathematics the art of properly stating a question is more important than the solving of it."[3]

According to the operational principle therefore only questions that involve operations are meaningful. But does not this place serious limitations upon our scientific constructions? The question has been raised whether the impossibility of direct or indirect observation precludes us from making scientific judgments concerning phenomena of whose existence we are reasonably certain.

For example, Ducasse inquired of Bridgman whether or not the question concerning the presence on the other side of the moon of a mountain 5023 feet high was meaningless. Bridgman replied it was not meaningless on the following grounds:

> ". . . a program of operations for the solution of it can be defined that has the following characters: It seems to involve no self-contradiction nor contradiction with anything we now believe to be true; it involves extensions of operations now performed by us only by amounts which do not seem prohibi-

[1] The Logic of Modern Physics, N. Y., Macmillan, 1927, p. 28; The Nature of Physical Theory, Princeton, Princeton U. Press, 1936, p. 11.

[2] Critique of Pure Reason, Müller trans., N. Y., Macmillan, 1911, p. 46. (Also in the Inaugural Dissertation).

[3] Cajori, F., A History of Mathematics, N. Y., Macmillan, (2), 1929, p. 397.

tive; and it seems possible of realization if we had sufficient material resources at our command."[1]

On the other hand, Lindsay raises the question whether an insistence upon laboratory operations does not put serious restrictions upon theoretical physics.[2] This writer quite properly places great value upon the concepts and hypotheses which precede and often suggest specific laboratory operations and make them intelligible. We must agree also with his and other methodologists'[3] accordance of a significant place to scientific intuition and imagination in scientific work. If Bridgman's operationism could not make room for such basic features of science it would be greatly at fault. It will be granted, however, that only such concepts and hypotheses as are based on previous operations with things, whether in the laboratory or in the field, can be scientifically valid. Furthermore, no theory can be scientific unless it involves operations or can have some part in actual observations. Lindsay implies the same when he disclaims emancipating theoretical physics from the test of experiment and when he declares that "a theory that makes no prediction which is within reach of experimental verification is no physical theory."

Now in view of Bridgman's original proposal and the questions it has stimulated we wish to suggest that the fundamental significance of the operational principle lies essentially in its implication that scientific work constitutes the behavior of specific individuals in relation to concrete objects and events. Science is then a form of interbehavior in which the nature of objects and events is determined not only by such first-hand operations as the reading of clocks, galvanometers and other instruments as well as the use of more elaborate experimental techniques necessary for close and accurate observation, but also by secondary operations derived from the former.

INTERBEHAVIORAL BASIS OF OPERATIONISM

Scientific operationism, we conclude, constitutes a special case of interbehavior. The psychologist describes an operation as an interbehavior of the organism with a stimulus object. Howsoever many intermediaries in the form of instruments, techniques, manipulations and modifications of the object are involved, we can never get away from this basic interbehavioral event.

The significance of the interbehavioral principle comes

[1] Ducasse, C. J., Verification, verifiability, and meaningfulness, *J. of Philosophy*, 1936. 33. 230-236.
[2] Lindsay, R. B., A critique of operationalism in physics, *Philosophy of Science*, 1937, 3, 456-470.
[3] See, for example, Campbell, N. R., Physics: The Elements, Cambridge, Cambridge Univ. Press, 1920. ch. 8.

sharply to attention when it constitutes a safeguard against the scientist's frequent dissipation of the phenomena he studies by the operations he employs. The classic illustration is the activity of the Renaissance scientist who in the interest of measuring operations reduced all qualitative aspects of nature to unrealities, thus practically liquidating nature in the interest of geometric ways of thinking. To be sure, we cannot but sympathize with the thinkers of the Renaissance who wished to banish Scholastic essences and qualities, but the remedy of making colors, sounds, temperature, etc., into phantasms or other sorts of unrealities is hardly to be preferred to the disease.

Bridgman himself falls precisely into this error when discussing the proof that π is transcendental. Quite properly he says that the statement that "π is either transcendental or is not" could not have been true in 1881 because only in 1882 did Lindeman demonstrate the transcendentality of π.[1] Here was a proposition that had to wait over two thousand years to be verified. But Bridgman, erroneously identifying the knower with the knowing or investigational operation, therefore does not agree that π was transcendental in 1881.

Possibly the π phenomenon yields only an ambiguous example, inasmuch as π is a ratio obtained by mensurating and calculating operations. Yet unless we overlook the fact that without something to operate upon we could not perform the operations, we cannot reduce operands to operations. That Bridgman does allow operations to swallow up operands follows from the fact that his view concerning π is explicitly based upon a denial of "the thesis that things have properties fixed and inherent, independent of anything that we may do about it."[2] Granting that the finest scientific constructions have in them factors not derived from contacts with independent phenomena, this does not free us from the conviction that an enterprise concerned with pure artifacts is not scientific. When Bridgman asserts[3] that from the operational point of view it is meaningless to attempt to separate "Nature" from "knowledge of nature" he is in our opinion departing from the operational point of view.

While we must always be on guard against building up a case on carefully chosen instances, we may ask whether by discovering its presence or computing its orbit the scientist does anything more than interbehave with an astronomical object with independent properties. When Halley computed the orbit of the comet named after him by comparing the

[1] The Nature of Physical Theory, p. 43.
[2] Ibid.
[3] The Logic of Modern Physics, p. 62.

observations upon (interactions with) it made in 1682 with those of earlier times, did he add anything to its properties?[1] There is also the case of Pluto which was photographed in 1914 and only discovered in 1930, that is, 16 years later. Who would claim that anything was added to its cosmic properties at either of these dates? To reduce properties to observations is to confuse the operations involved in discovering and determining the nature or naming of properties with the existence of the discovered properties themselves.

The writer therefore cannot agree with Bridgman in setting operations over against properties. Bridgman's objection to properties arises from his conception of them as absolute characteristics. His example is simultaneity, which before Einstein was regarded as a property of two events unrelated to anything else. Einstein, however, has shown that simultaneity can only be determined by mensurative operations performed by an observer with respect to the two events. Here an important question arises: Does the fact that the determination of simultaneity requires taking account of the position or velocity of the observer signify that simultaneity cannot be a property of an independent event system but rather a construction?

Granted that there are phenomena involving light signals, and cosmic distance in which simultaneity can only be a product of operations, this does not militate in the slightest against independent temporal coincidences. The work of the observer or experimenter cannot be assumed to rob a system of events of their objectivity. There is no reason to suppose that two parallel bells equally distant from the current source cannot be coincidentally activated by closing a circuit. Only by constructing abstractions excluding simultaneity in events can we convert properties into operations. This is nothing but a modified version of the venerable fallacy that phenomena exist only as our knowledge.[2]

Never do the boundaries set by ignorance or technological inefficiency to the scope of our operations warrant us in equating the activities performed while interacting with things, with the things themselves. That we cannot avail ourselves of subatomic energy, cure cancer, or transform species rather emphasizes the independent and objective existence of these phenomena than the opposite. When such phenomena (subatomic energy, cancer and species) yield to our operations upon them, those operations will be

[1] Except the property of being computed. It is possible that the equation $P_c = P_t$—that is, the identification of the properties computed with the total series of an object's properties—is the basis for solipsistic or subjectivistic doctrines.

[2] Pertinent here is Woodbridge's theory of knowledge or consciousness as natural history. See Woodbridge, F. J. E., The problem of consciousness again, *J. of Philosophy*, 1936, 33, 561-568.

entirely continuous with the other interbehavior in which we first became aware of those phenomena. We cannot conceive of scientific work in any other way than as beginning with a problem concerning certain phenomena whose properties and operations we are to discover, even though we frequently have to decide that a phenomenon which we thought existed really does not exist, inasmuch as it has been mistaken for something else.

This consideration is more significant for psychology than for the physical sciences, although the latter must also strenuously avoid all subjectivistic complications. The psychologist in particular, however, must determine whether the current conventional dualism influences him not only in setting up his operations, but likewise in injecting such cultural factors into his data. An interbehavioral operationism can do much to eliminate both of these undesirable conditions.

TYPES OF SCIENTIFIC INTERBEHAVIOR

While upon an observational level it is obvious that scientific operations constitute the interbehavior of a worker with actual things, so powerful are cultural traditions that scientific work is interpreted as at least sometimes concerned only with manifestations (in physics dial readings or in psychology verbal reports) or even with concepts that have nothing real to correspond with them. Hence it may be helpful to indicate how well the primary scientific procedures illustrate the interbehavioral principle.

(1) *Inquiry concerning the existence of a phenomenon* —The famous Michelson-Morley experiment illustrates one of the fundamental types of scientific interbehavior designed to answer the question whether a certain phenomenon exists. The question in this case was: Is there an ether? Maxwell reasoned that the electrostatic and electrokinetic forms of energy observed when electrical and magnetic forces were acting required that these energies be localized not only in electrified or magnetized bodies, but also in the space surrounding those bodies. He consequently assumed that there was a medium capable of becoming a receptacle for the two forms of energy.[1]

We are not concerned with the answer to the question. We merely want to point out that whether the Michelson-Morley experiment demonstrates that Maxwell among others arbitrarily constructed the ether out of mathematical equations, what those scientists did was to start with observable phenomena which led them to assume the existence of some other phenomenon.

[1] Electricity and Magnetism. Oxford Clarendon Press, (3), 1904, vol. 2, p. 432.

A similar illustration is afforded us by Hertz's research to demonstrate the existence of the electromagnetic waves predicted by Maxwell's equation.[1] In this case, of course, the existence of the phenomenon was not only established, but became the basis for radio-telephony and broadcasting. All this, as is well known, had its beginnings in the interbehavior of Ampére, Faraday, and Fresnel with electrical and light phenomena.

(2) *Investigations into the nature of phenomena*—In all cases in which the scientist inquires into the nature of existing phenomena the interbehavioral activity is particularly obvious. Here the primary question is what kind of properties are involved, The classic instance of the identification of light properties excellently discloses such interbehavior. While Newton regarded the rectilinear character of light propagation as a firm basis for giving it a corpuscular structure, Huygens relied upon observations of reflection and refraction to describe light as the vibration of an all pervading luminiferous ether.

That cosmic rays existed was comparatively long established before they were variously characterized as light quanta (photons) or particle streams. Not until ten years and more after their discovery by McLennan, Rutherford and others did the complicated operations upon them of Bothe, Kolhörster, Compton, Millikan, Rossi and others assume their very considerable amplitude. At this point we should like to indicate the continuity that exists between the interactions of scientists with phenomena from the earliest period of discovery to the investigation of properties and final construction of theories about them. Nor is it out of place either to indicate that scientific behavior is continuous also with everyday contacts of individuals with things.

Cancer pathology offers an especially telling illustration of scientists' complex preoccupation with phenomena in an effort to determine their nature. Considering that the annals of science are so full of such instances it is remarkable that room is left for the conception of a hiatus between science and the world of natural events, even though it is sometimes difficult—especially in physics—to observe the connection.

(3 *Interbehavior with Operations*—That properties and operations are not mutually exclusive is a fact with a distinct bearing upon the interbehavioral problem. It is apparent to every scientist that the identity of a phenomenon is determined by observing its activity. Whether the investigator operates upon the qualities, dimensions or motions of a thing or system he is in some form interbehaving with it.

[1] Hertz, H., Electric Waves, London, Macmillan, 1893.

Nevertheless many investigations not only in the biological but in the physical fields have to do primarily with the genesis and course of phenomena. Naturally, the biological and social sciences present the widest field for genetic and developmental observations, but certainly the problems of both celestial and terrestrial mechanics, whether classical or relativistic, are more or less concerned with the way the observed bodies operate. The science of heat and thermodynamics in general may be regarded as altogether a set of constructions concerned with the observational and probability operations of phenomena. Studies in quantum mechanics are similarly activities concerned with operations. The history of science is so replete with records of man's interbehavior with the way phenomena operate and especially those more or less inadvertently discovered (aniline dyes, cosmic rays, radioactivity) as to leave no doubt of the validity of the interactional formula.

(4) *Inquiry concerning specific interrelations of events* —The interbehavioral character of scientific work is nowhere better illustrated than in those investigations designed to discover interrelations between observed phenomena, as when we seek the conditions influencing the character of events. Today, when causation signifies the interrelation of factors in an event, it is plain that the scientist first ascertains the items constituting an event-complex and then inquires into the relative influence each exerts upon the other.

When we consider that all the interbehavioral forms of science are not only interrelated with each other but also with every sort of manipulation, casual observation, and other sorts of contacts of organisms with things, we immediately recognize that scientific operations are forms of interbehavior. We can go further and observe that scientific work is interbehavior even when the scientist is interacting not with events but with constructions. In the latter case he merely manipulates words, symbols, or propositions instead of independent objects.

(5) *Interbehavior with Relations*—Numerous generations of thinkers have expressed difficulties with the embodiment of stimulus objects. Some thinkers must have visibility and tangibility as criteria of objectivity, while others can readily ascribe independent reality to energy or vibration. The interbehavioral standpoint provides a definite criterion for objectivity. If we can actually interact with something, whether by its sheer impact upon us with or without specific consequences or by observing impacts and consequences between things without ourselves participating in them, those phenomena are stimulus objects for us. The obvious but baseless alternative is that we create that which we assert exists. Unlimited powers a speaking organism has

of verbally creating things. Such things are said to be subsistent and not existent. The process here is to build on our actual contacts with things and assert analogies, similarities, by verbal or graphic behavior. The things involving actual contacts are employed as substitute stimulation. We can, of course, regard those sheer analogical constructions as stimulus objects, but we never should confuse them with actual existents. All creative contacts with existents can only consist of manipulations and modifications.

All this is à propos of the interbehavior with relations. Relations are existents even though we must first discover them in order to interact with them. To interact with relations between tangible objects gives us no trouble. Masses or particles we discover attract each other directly as their masses and inversely proportional to the square of the distances between them. But there are more difficult problems involved in the interaction with more abstract relations. Take the famous question: Is there a number which indicates the number of digits in the number π at which, for the first time, the sequence 0123456789 begins in the decimal representation of π? Or consider Fermat's last theorem: There is no number $n > 2$ which will satisfy the equation $x^n+y^n=z^n$; x, y, z not being O. Whether or not there are such relations is precisely determined by whether we can or cannot directly or indirectly interact with them. Just as we may discover that some chemical compound inferred to exist really does not, so we interbehave through substitute stimulus objects with these relations, to end in the conclusion that there are no such relations. But whatever the result may be, it can only be determined by the sort of interbehavioral operations we have been depicting.

OPERATIONISM AND THE CONSTRUCTIONAL CHARACTER OF SCIENCE

All science is construction. Its materials are data consisting of records of observations. Observations are always forms of a scientist's interbehavior with objects and their properties, or events. These observations are translated into descriptions varying from sheer references concerning these events to the setting up of models, whether verbally descriptive analyses, curves, or mathematical formulae. Essentially characteristic of scientific activities is a definite continuity between the original approach to the primary events, through the manipulation and analysis of the crude data, to the final construction. Crude data, of course, are the things or conditions which stimulate the scientist to recognize a problem.

Construction begins with elementary reference. The original contact of the organism with an object we regard as

the fundamental observation. It is an act of O with respect to S, or an interaction between them as we may technically describe it. Then O refers to the phenomenon either by a gesture or some definite verbal pattern. This reference we may regard as nothing more than conversational speech and as such constitutes a construction of first approximation. This is the everyday man's construction.

The scientist elaborates this first construction on the basis of further observation consisting of additional handling preliminary to viewing the object from a different angle. Then, he may manipulate the object by performing various dissecting and analyzing operations and develop a quantitative construction with a final complicated model in the shape of a curve or mathematical formula or an even more complex model in terms of a set of differential equations.

The conventional names given to scientific constructions range them in a hierarchical series. At the base is put hypothesis, then theory, and finally law. In modern science the tendency is toward a greater and greater emphasis upon the relativity type of law, stated in terms of probability.

We are not at the moment interested in working out any prescription as to the order of these constructions, nor insisting upon particular terms to represent them. We may, however, demand that all the constructions be connected with the primary data or events by a substantial link of observation and observational procedure. When we take into account all the different scientific pursuits we shall have to pay attention to the details of field observations as well as laboratory experimentation.

The exigencies of scientific work may be such as to attenuate the thread binding the construction with events to a very thin calibre. There are questions of what is possible, needed, and useful. But it is an established maxim that this thread can never be broken. When the ratio of construction to observation is large we may still regard the speculative construction as scientific, but when the observational factor is zero we have no other alternative than to characterize the speculation as unscientific or non-scientific.

INTRINSIC AND ANALOGICAL ASSIMILATION OF SCIENTIFIC PRINCIPLES IN PSYCHOLOGY

Whatever conditions may have contributed to bring about the circumstance, the history of psychology is to a great extent a record of successive adoptions of scientific principles.

It is to the credit of psychologists that although their domain has been and still is regarded as concerned with things, properties and events in principle different from those of the natural sciences, they have nevertheless attempted

to borrow conceptions developed in those sciences. Among the earliest attempts is the introduction into psychology of the gravitational (Hume's association) and vibrational (Hartley) principles of Newtonian physics. Later, with the advent of the chemical element, psychologists (J. S. Mill, Wundt) made use of atoms as prototypes of psychological elements, compounds, complications, etc. When in the early 19th century, biology and physiology became well established their impact was felt in the development of physiological and genetic psychology. Still later, the turning of physics from the mere use of geometrical to analytical mathematics found its analogue in the Herbartian and Fechnerian development of psychological statistics. In our own day the preoccupation of physicists with fields has brought topological ideas (Lewin) into psychology.

Unfortunately, however, psychologists have persistently treated natural science principles as sheer analogies[1] and not as intrinsic investigative tools. At bottom this can be traced to the ingrained dualism engendered in the Hellenistic period of our culture, a tradition which has induced both physicists and psychologists to regard phenomena as primary and real on the one side and secondary and unreal on the other. Accordingly, the assiduous pursuit of laboratory investigation has not helped to extrude the psychic from psychology any more than laboratory studies have succeeded in driving out vitalistic principles from biology.

We probably should not regard the general use of laboratory techniques by psychologists as a mere imitation of the natural scientists. Rather, experimentation in psychology reflects the tremendous impact of technological culture upon all intellectual enterprises. The employment of experimental observations is an inevitable result of our cultural evolution. But since our culture is dualistic, it is only to be expected that psychologists believe they are making scientific determinations of psychic or conscious processes. Accordingly, Fechner regarded psychophysics as an exact science of the relations of the psychic and the physical and Ebbinghaus thought of his nonsense syllable techniques as a method of studying the higher mental processes. The physicist, who is just as much a dualist, simply turns the psychic over to the psychologist and proceeds to study the interrelationships of objective events. The psychologist, on the other hand, uses objective procedures to maintain his faith in mentalistic processes.

Psychological records are full of schemata designed to give the psychic the semblance of objective phenomena. Thus we find such expressions as "functions" and "dimensions

[1] See Kantor. J. R., Concerning physical analogies in psychology, *Am. J. Psychol.*, 1936, 48, 153-164.

of consciousness" and such assertions as "consciousness is an *act* of awareness" or "consciousness is a conceptual construction," though there is nothing out of which to construct it. All of these schemata constitute analogical borrowings from the physical sciences and take the place, for example, of descriptions of how individuals interbehave with colors, sounds, etc.

The operational principle figures in one of the latest psychological adoptions. Its fate in psychology is a precise duplicate of what has happened to so many other principles developed in the natural sciences. So eminently correct a principle as the operational procedure for the development of concepts and other scientific constructions could scarcely have failed to attract psychologists. As we have pointed out, operationism in the interbehavioral sense is merely a formulation of what scientists actually do in their attack upon the materials with which they work. We must then regard this principle as concerned with observational methods and procedures which bind together crude data and constructions and are therefore common to all sciences. Unfortunately, however, the operational theory, like most scientific concepts imported into psychology has not been intrinsically incorporated.

The failure, however, of psychologists intrinsically to assimilate particular natural science doctrines and points of view into their ideology should not be deplored. Does not scientific experience teach us that the differences in actual phenomena studied call for varying methods and techniques as well as different constructions? But we do assume that the operational principle is an important methodological tool applicable to all sciences. For this reason it is interesting to observe what psychologists have done with it.

OPERATIONISM IN PSYCHOLOGY

In general psychologists adopt two attitudes toward the operational principle, aside from verbally accepting it as a valid method of formulating definitions. On the one hand, the conventional sensation-psychologists have attempted to assimilate the principle, with the result that what has been proposed as a fundamental improvement in forms of physical science has been used to implement conventional dualism in psychology.

On the other hand, under the influence of conventional dualism psychologists have asserted that there are extreme limitations to the application of the operational principle in psychology.

As an illustration of the former attitude we refer to Stevens'[1] use of the principle. Existence, he asserts, is that

[1] The operational definition of concepts, *Psychol. Rev.*, 1935, 42, 517-527.

which provides a basis for differential responses, and when he says further that the existence of the earth means that normal beings make certain differential or discriminative responses to it as a stimulus, one might conclude that we have here an interbehavioral view. But this conclusion is soon dispelled when we see how far this differential response is carried.

According to Stevens everything reduces to differential reactions. All operations at bottom come to be discriminations which consume the discriminand. Red, and presumably the earth also, are never independent phenomena. They are created in the discrimination process. Assuming that red is always found in a discriminative situation, we might still ask why should the discrimination not be guaranteed by the red as well as the opposite? In general, for Stevens, there are no crude data; everything is construct. Thus all experience reduces to the sum-total of the discriminating reactions of human beings. Experience is itself essentially construct and there is no ultimate matrix in which organisms interbehave with other natural phenomena. A genuine operationism on the contrary presupposes a continuum in which constructs, as well as knowledge, are members of a series which include prior contacts that can in no sense be called constructs but rather elementary adjustments. Perceptual interbehavior in this series is decidedly not knowledge, especially if we really believe, as the mentalists are beginning to, that perception is not different from sensing.[1]

Obviously we have here such a truncation of the operational conception as to convert it into a thoroughgoing subjectivism. In fact, this is nothing more than a modified Berkeleyanism.[2] Despite the verbal insistence upon discrimination as physical and the inevitable acceptance of psychological phenomena as interbehavior when actual experiments are described, Stevens' adoption of the operational principle comes to nothing more than a mentalistic psychologist's surface concession to objectivity. Whether or not we have a genuine objective view depends upon a writer's technical constructions. We must ask what is a stimulus for him. Stevens' answer is clear when he asserts that sensation reduces to a differential reaction by an organism to stimulation of a sense organ which varies concomitantly with changes in the stimulus. Since everything for Stevens is construction and all science is public state-

[1] That perceiving and sensing are not different forms of interbehavior objective psychologists have long pointed out. (see, for example, Kantor, J. R., Principles of Psychology, N. Y., Knopf, 1924, vol. I). Mentalists are now adopting the view, but paradoxically enough for the purpose of supporting their psychoneural doctrines.

[2] Cf. Stevens. S. S.. Psychology, the propaedeutic science, *Philosophy of Science*, 1936, 3, 90-103.

ment, it is obvious that he has merely adapted the operational principle to implement the traditional mentalistic correlation of subjective qualities with the operation of a sense organ stimulated by radiation.

Concerning the limitations of the operational principle McGeoch[1] asks whether it can be applied to subjective qualities. He quite properly points out[2] that behind such discrimination as Stevens insists upon lies the criterion of quality in terms of which the discriminations were made. All protestations notwithstanding, sensation qualities in the final analysis are nothing but transpatial and hence unreal constructions. The typical view is illustrated by the following quotation:

> When we say we hear, we mean, usually, that we experience sensations which have been produced by the excitation of the auditory mechanism. These elementary experiences . . . are called sounds. Yet such sounds have no objective existence; outside ourselves all is quietness. Externally there are simply bodies in vibration.[3]

Obviously when such factors comprise a part of a scientific system severe limitations are placed upon it. But the question arises here: Why harbor such factors which no observational technique can handle rather than tie to the interbehavioral principle which is in itself a criterion for the admissibility of any factor either as a datum or as a construction?

Now as a matter of psychological record, whatever accumulation of facts psychology can boast of has been accomplished by the employment of operational techniques involving organisms on the one side and actual objects, conditions, and situations on the other. No psychologist has ever studied visual, auditory, tactual or any other kind of quality except as differential responses of organisms to colored, sounding or solid objects. He has observed the interbehavior of the organism to such objects. All of his constructions, all of his laws have been formed on this basis.

Only conventional dualistic suppositions have induced the psychologist to think that he was studying the response of tissues to light rays or air waves. This means that on the stimulus side he has substituted for his original crude data constructions developed by the physicist for other situations altogether.

The objections raised against the operational principle on the ground of subjective qualities constitutes merely the

[1] A critique of operational definition (paper read at Minneapolis meeting of the American Psychological Association, Sept. 1937).
[2] In a letter to the writer.
[3] A Handbook of General Experimental Psychology, Worcester, Mass., Clark Univ. Press, 1934, p. 880.

injection of mentalistic presuppositions into the science of psychology. It is precisely the following out of interbehavioral operations that negates entirely all subjective quality constructions. It would be a calamitous failing on the part of the psychologist not to notice that in his own constructions he should rather build on observations which in the first instance involve an organism that for psychological purposes can never be reduced to specialized partial mechanisms. On the other side, the colored or sounding stimulus objects need not ever be converted into the abstractions of the physicist. So far as color is concerned the psychologist studies the interaction of the organism with color which can be analyzed chemically and physically.

Why the term subjective in psychology? We are passing away from the grand tradition dating back to medieval times of dividing the universe into primary and secondary qualities. That dichotomy was never based upon any observation, but rather upon a series of scientific accidents which made the geometric constructions of mechanics into the prototypes of science. Actually the only operational basis for such a term as subjective is that the differentiation of color, say, is an activity of a particular organism which may vary from that of some other organism. Such relativity of discrimination based upon the diverse reactional biographies of individuals, varying illumination or other setting, hygienic conditions, and differences in interbehavioral position between individuals and objects can all be objectively described, just as the physicist describes the relativity of time, motion, mass, and energy.

Neither does particularity any more than relativity imply subjectivity. Hence, particularity places no limitation upon any operation interbehaviorally conceived. We all know that every event in the physical domain is also particular and that no physical law is ever exactly demonstrated in every physical event of which it is a construction.

Scientists carry into the laboratory their scientific traditions as surely as they carry their linguistic cultural background into their conversation. The general process here is uniquely isotropic. Indeed, the psychologist's criticism that the operational principle is impotent in the face of subjective qualities can be correctly viewed as the imposition of cultural preconceptions upon new situations.

SCIENTIFIC CONSTRUCTION IN PSYCHOLOGY

To review some of the typical constructions in psychology is to conclude that a valid operational principle is not at home in that field. As a test of this conclusion we examine the way color perceiving is described, since that subject is generally regarded as one of the scientifically best estab-

lished. The typical description contains at least eight specific fallacies or errors which may be listed as follows.

Construction by:

1. Abstractional borrowing
2. *Ex nihilo* creation
3. Traditional imputation
4. Conversion of data
5. Misinterpretation
6. Arbitrary reduction
7. Ignoring facts
8. Making wholes of parts

These errors are present either in the direct description or in its implications.

Stimulation—Our typical description starts with the impact of light rays upon the eye. Patently the construction begins with an abstraction borrowed from physics. In itself the borrowing is no evil except insofar as it breeds bad description. But in addition there are serious difficulties. First, what if light is not a traveling thing?[1] Again, what if light consists of corpuscles instead of waves? Secondly, the description assumes that there is monochromatic light, possibly another incorrect assumption.[2] Thirdly, there is no definite correspondence between wave frequencies or lengths and color qualities, though under certain arbitrary conditions the physicist may establish one. And finally, in view of the fact that the organism is constantly immersed in light media and is in contact with numerous objects possessing all sorts of colors, how assume that a particular light wave starts a particular neural impulse corresponding to a particular color quality?

The description of color perceiving as a process of starting off a particular neural impulse to eventuate in an experienced color quality may be characterized as a *start from rest* construction. Aside from all the other difficulties that such a construction entails we have to take account of the physiological finding that the operation of the receptor mechanism is inessential in bringing about cerebral activity.

> It is observed that, even when no stimulation is applied, when the optic receptor is not deliberately excited, there is, nevertheless, a continuous activity exhibited in all parts of the brain.[3]

Added to the error of abstractional borrowing we have also the errors of arbitrary reduction and ignoring facts.

[1] Bridgman, P. W., The Logic of Modern Physics, p. 150ff.
[2] Wood, R. W., Physical Optics, N. Y., Macmillan, (3), 1934, pp. 11-12.
[3] Gerard, F. W., Brain Waves, *Scientific Monthly*, 1937, 44, 48-56.

Our typical construction is designed really to describe how we perceive colors, but to accomplish this end, color perceiving is taken out of the rich and varied matrix in which individuals actually adapt themselves and forced into the restricted domain in which everything is ignored except a single kind of color. The fact which we start out to describe is therefore reduced to something else. Let us not forget that we start out with all sorts of colors from different objects, textures, surfaces, pigments, etc., and confine our description to colored light. But perhaps one of the most serious errors is that we are really assuming, as the quotation above and the one to follow indicate, that we are not dealing with natural colors at all. Thus we fall into the *ex nihilo* error of creating color where none really exists.

The source of the *ex nihilo* error lies, of course, in the dualistic character of our psychological traditions. We need go back only to Newton for an excellent example of what sort of formulation this tradition leads to. In the Opticks Newton writes:

> If at any time I speak of light and rays as coloured or endued with Colours, I would be understood to speak not philosophically and properly, but grossly, and according to such conceptions as vulgar People in seeing all these Experiments would be apt to frame. For the rays to speak properly are not coloured. In them there is nothing else than a certain power and disposition to stir up a sensation of this or that Colour. For as sound in a Bell or musical String, or other sounding Body, is nothing but a trembling Motion, and in the Air nothing but that Motion propogated by the Object, and in the Sensorium 'tis a sense of that Motion under the form of sound; so Colours in the Object are nothing but a disposition to reflect this or that sort of rays more copiously than the rest; in the rays they are nothing but their dispositions to propogate this or that Motion into a Sensorium, and in the Sensorium they are sensations of those Motions under the forms of Colours.[1]

As Nagel says:

> Whatever plausibility this argument possesses is due, as has been repeatedly pointed out, to the confusion of the conditions and means of perception and knowledge with the perception and knowledge of those conditions and means. The fallacy in the "nothing but" argument is seldom revealed elsewhere with so much clarity.[2]

[1] Opticks. 1704, I. pp. 90ff.
[2] Nagel, E., On the Logic of Measurement, Columbia Univ. Doctoral Dissertation, 1930, p. 41.

As a physicist Newton could adopt such dualistic views and still achieve scientific victories. Not only could he introduce quantitative methods into the optical field, but make way for a future unification of optical, mechanical, thermodynamic and electrical constructions. All this was possible because he made colors unreal in order to provide a basis for the investigation of the interaction of differently refrangible rays and prisms that would disperse them. Physicists today believe Newton was mistaken in his idea of the interaction. Instead of saying that the rays for all the colors are in the white light or the original beam they now believe that the prism or grating really produces them.[1] This does not detract, however, from Newton's employment of an operational principle.

But what about psychology? Newton had his theological resources to supply flesh and skin with which to cover his bare length, time and mass skeleton of the universe. Now that science has only the world of nature to deal with we can see that traditional dualism constitutes a disease from which psychology never is but always is to be cured.

It may not be improper to interpret modern science, with its emphasis upon specificity of occurrence and the organization of event factors relative to each other, as making way for the description of phenomena on their own basis without submerging them in borrowed or invented abstractions.

End-Organ Reception—For the receptoral phase the conventional construction assumes that retinal structures (cone cells) are differentially sensitive to varying wave frequencies. At this point again there is analogical borrowing. Instead of keeping close to the crude data of the organism's interactions with all sorts of colored objects, the construction is based upon the analogy of color mixing and matching. Whether one accepts the Young-Helmholtz construction of three primaries R, B, and G or the Hering theory which adds Y as a fourth, the stimulation of these photosensitive retinal elements with their connected optic nerve fibres and cortical projection is regarded as producing corresponding color sensations.

As physiologists well know, there are few retinal facts to build on when differentiation is required. As we shall presently point out, in the face of binocular fusion physiologists take color functions away from the retinal elements. Again, the fact that retinal inversion of images makes no difference to space relations should have an effect upon our view concerning receptoral function. And finally, we may take into account recent views concerning the cutaneous receptors. For example, Nafe declares that:

[1] Wood, R. W., Physical Optics, 1934, p. 1.

> After fifty years of investigation we have no demonstrated correlation between any particular type of sensitivity and the specialized end-organs and fibres that subserve it.[1]

Perhaps a more serious obstruction to this theory is the fact that the neural impulses presumed to be set up when different light rays operate on the photosensitive substances are not qualitatively different from different sensory fibres or even motor conduction. Nevertheless the psychologist bravely carries on. Operating in the dualistic tradition and believing, as we have indicated, that qualities are psychic or unreal, psychologists must find a locus for them in some organic tissue. Consequently they assert that the brain must be that organ in which consciousness is localized. This is tantamount to the belief that the brain discriminates, really creates qualities.

Neural Conduction—Since the purpose of our illustrative construction is to find correlations between physical processes and psychic color qualities, particular correlates must be supposed between given retinal and cortical processes. At this point the error of traditional imputation is exemplified at its crudest. Properties are imputed to pathways in the absence of the slightest evidence of specific conductive energies, even when the innocent brain is included. Resort is here made to the crude fact that we do distinguish colors, at least 180 different ones in the visible spectrum. Is it anything more than traditional bias that demands that we must have differential conduction for these? Not, we believe, unless we start with the presupposition that we are dealing with psychic qualities on the one hand and physiological processes on the other. Perhaps we have here a complete misinterpretation of what a psychological construction must accomplish. Why should visual perception be a matter of physiology altogether?

Brain Centers—In the drama of perceptual and general psychological description the brain is the *deus ex machina* which knows everything and does everything. How? By ascription, conversion, ignoring facts and by making wholes of parts. When physiology teaches us that we cannot correlate sensations or discriminations of specific color qualities with receptoral or conductive elements, the proponents of the conventional construction are forced to find a differentiating medium in the cortex. But is there the slightest evidence of such differentiating factors in the cortex? It is plain that only by ascription of "functions" to "centers" and by converting physiological processes of conduction can the construction proceed. What neurological or physiological

[1] Handbook of General Experimental Psychology, Worcester, Clark Univ. Press, 1934, p. 1041.

basis exists for interpreting the activity of the brain as anything else but a conductive and integrative mechanism? Why should the nervous system have to carry all the explanatory burden when its functions constitute only a part of a psychological response, and further the total response is but one part of the perceptual interbehavior with things?

Investigators of neural anatomy and physiology do not hesitate to acknowledge the dense cloud of ignorance that hangs over the workings of the brain. Adrian declares that "we know far more about our thoughts and actions than we do about the mechanisms in our brains."[1] In a similar vein Lashley writes:

> Symptoms involving purely sensory or motor defects have the most certain diagnostic value; a monoplegia or a limited zone of cutaneous anesthesia are surely indicative of a focal lesion whose position may sometimes be predicted within a few centimeters. But a defect of color vision, a disability in reading, an apraxia, or a syntactical aphasia are indicative only of disturbance somewhere within a rather widely extended field, while a simple defect of judgment or change in personality, even when of unquestionable organic origin, can not now be associated with any cerebral locus.[2]

Again, Ranson asserts:

> I shall leave out of account entirely the most difficult part; how when these propagated disturbances reach the brain they give rise to conscious sensation, which appears to be something of an entirely different order than a neural activity. I can not understand how such a thing as a sensation of warmth makes its appearance as a result or as a concomitant of the activity of certain nerve cells in my brain. *I can only admit the fact* and leave to the future, perhaps the far distant future, the problem presented by the relation of brain and mind.[3]

As the above quotations indicate, those writers who have difficulty with brain factors still accept the cerebral dogma. Their writings are on that very account all the more informing because they so clearly reveal the gap between neural knowledge and the conventional beliefs heaped up on top of that knowledge. Do not these quotations signify that while neural factors as inevitable features of psychological behavior must be included in descriptions of such behavior, they cannot be used as mechanisms to explain the occur-

[1] Adrian, E. G., The nervous system, *Science*, 1936, 84, 275-278.
[2] Lashley, K. S., Mass action in cerebral function, *Science*, 1931, 73, 245-254.
[3] Ranson, S. W., Cutaneous sensation, *Science*, 1933, 78, 395-399 (our italics).

rence of the larger interbehavioral phenomena of which they are parts.

One of the worst features of the psychoneural theory is that it encourages the error of ignoring physiological facts. Graham points out:

> The discussion has given abundant evidence to show that the visual response is not a direct representation of the excitation in the end-organ or afferent pathways. Trains of impulses which reach the central nervous system by way of the peripheral nerve fibres are modified by and combined with impulses from similar and dissimilar end-organs.[1]

We should, if his view is correct, radically revise our perceptual constructions.

Practically all the errors of perceptual construction are excellently illustrated in the consideration of the binocular fusion of color. When one looks at red with one eye and green with the other, the subject reports a fusion to form yellow.[2] Immediately this is interpreted as a fusion in the brain, despite the fact that there are no possible means of connecting colors with brain processes. Does neural physiology teach that the brain is a terminal system or a dense mass of junctions—interconnection points for circuit systems? Is the terminal idea not merely a reflection of the old cultural belief that the brain is the seat of the soul? Does neuro-physiology provide a basis for any other construction except that the nervous system is a conductive and coordinative mechanism, even if the circulating mechanism is also an integrative system?[3]

Are not the putative powers of the brain to discriminate (create) colors slender foundations upon which to build a color perceiving construction? The poignancy of the question is intensified when we observe that this hypothesis virtually denies the capacity of the retinal cells to function in color discrimination. Notice that the conventional construction assumes that the discrimination of G from R is mediated by different proportions of the R, G, and B photosensitive substances in connection, of course, with brain cells. But the ascription to the brain of binocular fusion or the power to produce sensations robs the retinal substances of their functions altogether.

All of these difficulties arise in the consideration of color perception, a most favorable type of phenomenon from the standpoint of conventional theory. In ordinary perception,

[1] Handbook of General Experimental Psychology (Worcester), Clark Univ. Press. 1934, p. 874.

[2] Cf. Hecht, S., The nature of the photoreceptor process, in Handbook of General Experimental Psychology, ch. 14.

[3] Cf., Cannon W. B., The integrative action of the vascular system, in Human Biology and Racial Welfare, N. Y., Hoeber, 1930, ch. 10.

however, when complex objects and situations are interacted with, there is simply no hope of making available the conventional constructions. In view of this situation we propose a revised construction following the lead of the crude data—namely, that the organism interacts with colors. Instead of building upon traditional brain mechanisms we may take into account an operational field in which an organism is in contact with colored objects or patches with a series of surrounding conditions. Upon this basis such ideologically disturbing factors as the master tissueship of the brain and the existence of sensations vanish in favor of actual events.

INTERBEHAVIORAL EVENTS VERSUS NEURAL POWERS

Our discussion so far implies conclusively that the power of conventional ideas as they are centered in neural traditions prevents the acceptance by psychologists of an authentic interbehavioral view. The unwitting acceptance of traditional postulates interferes with the building of constructions upon observable phenomena.

There is no better established fact in all of psychology than that every psychological event on the response side of the interbehavior includes the complex participation of numerous organic factors. But only by properly evaluating these factors can the interests of science be served. The first result of such an evaluation is the realization that psychology cannot describe its phenomena in cerebral or other neural terms. On the contrary, not only is the cerebral dogma the stumbling block in the way of operational description, but also the source of the errors we have indicated. In scrutinizing the following questions we can gauge the ratio of observation to traditional theory in psychological constructions.

Do the neural tissues have dual functions? Why should psychologists assume that the neural tissues in contradistinction to all others have two functions? Neurologists and neurophysiologists are satisfied that the nervous system is a conductive mechanism operating to coordinate and integrate the organism's movements and other activities. Why the extra psychic functions except in answer to dualistic tradition? Today we can be just as certain that all the other tissues participate in the performance of a psychological act. We may, if we like, regard the glands of internal secretion as determiners of psychological action or as the loci of mentalistic thought, motion, etc. Destruction and malformation of such tissues lead to just as vital impairment of perceiving as neural destruction.

Are psychoneural concepts descriptive or assumptive? If, instead of falling into the tradition that the brain is the

organ of psychological processes, we inquire into the basis of this tradition we find a peculiar reversal of scientific technique. Instead of brain interpretations arising from observations we find that the observations have been fitted into a preestablished system. However useful physiological theories may once have been in bringing psychological descriptions down from the clouds, it requires no great perspicacity to see that today these same theories operate to keep psychological descriptions from being naturalistic. Strange that the phenomena of physiology should be so misinterpreted as to support psychic constructions!

Are there higher and lower brain centers? Coming down to more specific issues, what is the basis for the belief in higher centers for learning and intelligence and lower centers for reflexes and habits? Undoubtedly there is a correlation between the complexity of the neural structures, including the evolution of the cortex, and the complexity of actions that organisms perform. On the other hand, when we find that the destruction of the cortex does not interfere with what are probably the most complex actions an animal can perform the traditional views prompt the retort that the lower centers take over the functions or perhaps have always had them. This leads to the impossible conclusion that the cortex really has no necessary function at all.

The writer has pointed out long ago[1] that the dualistic theory of neural functions implies questionable assumptions. First, psychological phenomena in all their complexity are reduced to "functions" of anatomical structures, similar to actual physiological functions. And secondly, on account of this tradition all the complex interbehavioral facts we actually observe are set aside, including the total and unified action of the organism.

Can tissue losses be connected with psychoneural functions? The insidious influence of tradition in psychological construction is apparent in localization discussion. Plainly, the only basis for the belief that there are specific psychoneural functions is the observation that losses or destruction of certain neural tissues lead to behavior interferences. Conventional neural doctrine demands the conversion of the fact, that when a part of a neural or any other structure which participates in a certain response is injured that response is interfered with, into the altogether different conception that the action is localized in a neural structure.

How should neural extirpations be interpreted? When an experimenter reports that the extirpation of large amounts of cortical tissue results in a greater proportional reduction

[1] The nervous system, psychological fact or fiction? *J. of Philosophy*, 1922, 19, 32-49.

of capacity to form maze habits as compared with smaller tissue losses, what interpretation should be placed upon these facts? The literature reveals that the answer depends upon the interpreter's presuppositions. Those who hold to the cerebral dogma naturally find support for their particular view, though the question arises why we should not find it remarkable that badly mutilated animals should be able to form such habits at all. In view of the alternative interpretation that even mutilated organisms can interact with stimulus objects, such constructions as the shifting and vicarious operation of neural functions appear to be products of presuppositions rather than actual observations.

What value can be placed on clinical findings? The slight repercussion in psychological writings produced by the findings of radical brain operations constitutes one of the most striking instances of the influence of traditional views and the neglect of facts adverse to such traditions. When Dandy asserts that neither the removal of the whole right hemisphere or the frontal, occipital or temporal lobes of the left hemisphere interfere with a person's complex psychological activities, and only when the left cerebral artery is injured is the consciousness of the patient interfered with,[1] he hardly produces a stir in the psychological camp.

What are the results of learning investigation? Results favorable to a neural explanation of psychological phenomena should be found in the learning field if anywhere. For learning investigations not only are concerned with the simpler and cruder human activities, but with the comparatively gross actions of animals. It is significant therefore to observe the conclusions of an assiduous student of neural functions in psychological behavior.

> The conclusions from this review of the problem of learning must be largely negative. In spite of the vast experimental literature which has grown up since the studies of Ebbinghaus and the advancement which has been made in the study of nervous structure, it is doubtful that we know anything more about the mechanism of learning than did Descartes when he described the opening of the pores in the nerves by the passage of animal spirits. His statement sounds remarkably like the reduction of synaptic resistance by the passage of nerve impulse.[2]

[1] Dandy, W. E., Changes in our conceptions of localization of certain functions of the brain, *Am. J. of Physiology*, 1930, 93, 643; Physiological studies following extirpation of the right cerebral hemisphere in man, *Bull. Johns Hopkins Hosp.*, 1933, 53, 31-51; The brain, in *Lewis, Practice of Surgery*, 1933, vol. 12, ch. 1.

[2] Lashley, K. S., Handbook of General Experimental Psychology, p. 493.

CONTINUITY OF SCIENTIFIC OPERATIONS AND GENERAL INTERBEHAVIOR

The performance of operations upon phenomena, whether for purposes of identifying and defining them or for discovering a law of their operation, is a process in principle like all interbehavior of organisms with things. In this sense we may agree with those who minimize the novelty of the formal operational principle,[1] though this lack of novelty enhances rather than lessens the value of the principle.

If it is correct to characterize the operational principle as an interbehavioral phenomenon, a particular preoccupation by the scientist with things and events preparatory to describing and evaluating them, then this fundamentally signifies that the operational principle both in its origin and use is an objective phenomenon.

Basic to all scientific thinking is the assumption that all natural happenings comprise ways in which their constituting factors interbehave with each other. When such natural events come to the notice of organisms a different form of interbehavior is set up. Now the organism interbehaves with interbehaving phenomena, and these phenomena constitute crude data whenever the organism enters into any sort of investigative procedure with them. Scientific observation, then, signifies an elaborate form of contact of human organisms with the objects around them. Scientific as compared with prescientific interbehavior implies sophistication—a background of many previous interactions with such crude data. For the scientist, crude data always present a fairly definite problem concerning nature and mode of operation and may be handled either on the basis of superficial resemblances and traditional attitudes or by a new analysis and experimental manipulation. The result of this interbehavior will be the construction of a theory or law concerning the crude data.

From this homogeneity of scientific investigation and the simple contacts of individuals with surrounding things we wish to draw a particular conclusion. Such homogeneity makes it possible for us to enlarge the scope of the operational principle beyond the mere criticism of concepts to include the checking of laboratory or other observational procedures as well as the formulation of postulates.

INTERBEHAVIORAL CONTROL OF SCIENTIFIC OPERATION AND POSTULATION

Granting that all science is relative, it follows that any scientist's activity can be subjected to rigid methodological control. We may and frequently must ask how a particular hypothesis or experimental procedure fits into its specific

[1] McGeoch. J. A. A critique of operational definition, (abstract) *Psychol. Bull.*, 1937, 34, 703-704.

scientific framework. This inquiry is similar to that of ascertaining whether any particular tool is or is not adapted for a certain purpose. The same principle applies to the general presuppositions involved in formulating our problems and making our interpretations.

Control of Investigative Operations—There are several considerations implied in the conception that scientific operations constitute ways in which individuals interbehave with particular phenomena.

In the first place, the emphasis upon the observer cannot minimize the stimulus objects with which he is interacting. The scientist's elementary descriptions as well as his more complex constructions can only begin with such interbehavior, whether they are simple, immediate observations or complex experimentation. We can always distinguish between his interbehavior with events and with his own constructions. Only by checking the behavior of scientists can we avoid the acceptance of subjective or purely arbitrary constructions. It is notorious that a tissue of metaphysical gossamer must always be spun to complete whatever web is begun with arbitrary threads.

In the second place, operations must vary with the specific phenomena investigated. If the problem is to ascertain the linear dimensions of a surface, the laying down of a rigid rod is sufficient. When a solid is involved, the operations as well as the instruments must conform to the difference in the investigative objects. The most complicated laboratory experiment must be consonant with this rule.

Every scientist knows that scientific descriptions and other constructions are conditioned by the particular apparatus and technique employed. With the Compton set-up, light operates as particles, but in Davisson and Germer's experiment on the defraction of electrons by crystals of nickel, light acts as waves. We quote Nagel's[1] reference to Lord Rayleigh's remark that:

> . . . the regularities which are observed in light waves that had passed through prisms or gratings may be the work of the spectroscope, and the number of bright lines observed in the spectrum is a function of the resolving power of the instrument and proves nothing about the regularities in the original light pulse.

Of interest here also is Bridgman's argument against carrying over a principle derived from certain data to others, and in general against undue statistical extrapolation.[2] Effective illustrations of the influence of investigative meth-

[1] On the Logic of Measurement, p. 42.
[2] Bridgman, P. W., Statistical mechanics and the second law of thermodynamics, *Science*, 1932, 75, 419-428.

ods upon psychological observations exist in abundance, and they all point to the inescapable necessity to scrutinize our operations in order to avoid partial or incorrect results.

Though the study of the way the scientist interbehaves with his stimulus objects can extend a few steps, this cannot imply an unreasonable regress, since our total system, concerned as it is with specific problems, has definite boundaries.[1] At the lower limit we have the everyday natural phenomenon of A interacting with B. This may lead to more elaborate observations and manipulations of the scientific sort. Then C may have A $\longleftrightarrow$ B as his field of operations, as when the scientist observes his students at work. The critic of C, namely D, studies how C investigates the study of B by A. Only by means of verbal construction can we carry this chain or system beyond a limited regress.

Control of Scientific Postulation—The interbehavioral modification of the operational principle applied to postulation is primarily concerned with the question whether the ideological basis of scientific work is derived from interaction with events or from cultural formulae. The interbehavioral principle, therefore, must be taken into account when we consider the more definite constructive operations of science[2] as well as when we scrutinize the manipulative operations with which they are continuous.

While in all interbehavior, as the term is meant to imply, stimulus objects are emphasized quite as much as the scientist's action, the way the stimulus objects are approached differs. How far are investigators influenced by (1) particular scientific or general cultural traditions or by (2) their contacts with events?

The influence of cultural traditions in science is a frequent and well recited tale. The classic example is, of course, the mathematician's struggle to achieve liberation from Euclidean authority. As the mathematical historian put it, this liberation was accomplished by drawing a sharp division between axioms=self-evident truth and postulates=assumptions.[3] While the author of the Elements of Geometry himself may have had an inkling of the postulational method it required more than two thousand years to provide it a footing in mathematics. Curiously enough, the postulational idea came to us not by the definite suggestion that Euclidean geometry was not *the* geometry, but by attempts to prove that it was. It was Saccheri's *reductio ad absurdum* proof of the parallel postulate that turned out to be an entering

[1] From the interbehavioral standpoint we do not sympathize with the criticism that one cannot check operations by operations without entering upon an infinite regress; Cf. McGeoch citation above.

[2] Namely, the scientific intuition and free imagination mentioned above.

[3] See, for example, Huntington, E. V., The method of postulates, *Philosophy of Science*, 1937, 4, 482-495.

wedge toward the final realization that geometrical postulates are constructs not based upon the absolute nature of space. It is significant too that Lobatchevsky called his distinctly non-Euclidean geometry imaginary.

Though we all share the common belief that mathematics is the most exact of man's intellectual occupations, it need not surprise us that it required so long to discover that mathematical systems are constructions based upon chosen premises. After all, the mathematician deals with things only remotely connected with observable phenomena. If geometry has to do with space at all it is a space derived by extreme abstractions and eliminations. But even in the most abstractive occupations we can see the value of an interbehavioral control of our thinking. Important questions are: What kind of stimulus objects are we interacting with and where if at all are those stimulus objects located in actually occurring events? A more closely focalized question, of course, is: How closely are we dominated by group conventions?

Let us not overlook the fact that since scientists are men and citizens they are bound to be victims of their culture and its history, but, as social psychology as well as anthropology teaches[1], culture changes through the behavior of individuals; so it is not a far-fetched admonition to be alive to our interbehavior.

It is an argument for the homogeneity of all the sciences that the origin of postulation principles in mathematics really represents modifications in the character of our culture. As Gulliver heard Aristotle say while on his voyage to Laputa, new systems of nature, even those demonstrated from mathematical principles, are only new fashions varying in every age, an observation which Schrödinger[2] has also made. The moral here is plain. Even though we may believe that we must somehow be in contact with nature, else how could we have any workable science at all, we must be constantly alert to the aberrations imposed upon our vision by conventions. Observe the arguments of competent and eminent scientists constructed to oppose such scientific novelties as evolution of species and relativity of physical phenomena, and behold the contrast between interbehaving with phenomena on the basis of established presuppositions and interbehaving without such hampering restrictions.

It is hardly necessary to enlarge upon this point when psychology is concerned. We need only refer to the persistence with which the dualistic tradition influences psychologists to extract their phenomena from the nervous sys-

[1] Cf., Kantor, J. R., An Outline of Social Psychology, Chicago, Follett, 1929.

[2] Schrödinger, E., Science and Human Temperament, N. Y., Norton, 1935.

tem. Traits and intelligence are regarded as manifestations of the organism's constitution rather than ways of interbehaving derived from former contacts with things. Mentality is a property of biological organisms which have only to mature to display their mental characteristics, etc.

Psychologists, of course, do not fail generally to accept an ideal of objectivity. It is interesting therefore to see how they attempt to avoid it if only verbally. Thus it is asserted that the relation of mental and physical is a philosophic not a scientific problem, but whether psychological phenomena really leave room for such a dualism is not questioned. Again, psychologists renounce any interest in systematic construction on the plea that sufficient unto the day are the laboratory data thereof, whatever they may amount to. Furthermore, we have the edifying declaration that the mental and the physical are really one. Sensations or mental qualities are neural impulses. Everything we find but the willingness to check the cultural influence of dualistic postulates by adhering rigidly to an interbehavioral principle.

INTERBEHAVIORAL OPERATIONS AND LINGUISTIC ABSTRACTIONISM

Since the sciences are all operational enterprises issuing from the same source and tending toward the same goal, vigilance over the operations exercised in one redounds to the benefit of all. Physics no less than psychology must constantly resist the lure of inherited tradition. The subjectivistic siren, whether in the guise of Machian sensations or mathematical abstractions, can be constantly observed leading physicists astray from concrete phenomena. Those physicists who in whatever form embrace sensations as the ultimate reality not only depart from the field which nourishes them, but also provide psychologists with grave temptation.

Though for the scientist, whether physicist or psychologist, nothing can be more fraught with danger than adherence to cultural tradition, he must be equally on guard against building his whole edifice upon particular kinds of investigation. In all probability these two tendencies are closely related. When the physicist allows himself only phenomena of high velocity or subatomic energy as building stones or when the psychologist erects his whole science on simple color discrimination we do not so much wonder that they build so badly as that they can build at all. Characteristic of our age is the appeal of inflated abstractions. Possibly the nth dimension of such abstractions appears in the linguism of the new positivism which asserts that the raw material of science is nothing more than a series of proposi-

wedge toward the final realization that geometrical postulates are constructs not based upon the absolute nature of space. It is significant too that Lobatchevsky called his distinctly non-Euclidean geometry imaginary.

Though we all share the common belief that mathematics is the most exact of man's intellectual occupations, it need not surprise us that it required so long to discover that mathematical systems are constructions based upon chosen premises. After all, the mathematician deals with things only remotely connected with observable phenomena. If geometry has to do with space at all it is a space derived by extreme abstractions and eliminations. But even in the most abstractive occupations we can see the value of an interbehavioral control of our thinking. Important questions are: What kind of stimulus objects are we interacting with and where if at all are those stimulus objects located in actually occurring events? A more closely focalized question, of course, is: How closely are we dominated by group conventions?

Let us not overlook the fact that since scientists are men and citizens they are bound to be victims of their culture and its history, but, as social psychology as well as anthropology teaches[1], culture changes through the behavior of individuals; so it is not a far-fetched admonition to be alive to our interbehavior.

It is an argument for the homogeneity of all the sciences that the origin of postulation principles in mathematics really represents modifications in the character of our culture. As Gulliver heard Aristotle say while on his voyage to Laputa, new systems of nature, even those demonstrated from mathematical principles, are only new fashions varying in every age, an observation which Schrödinger[2] has also made. The moral here is plain. Even though we may believe that we must somehow be in contact with nature, else how could we have any workable science at all, we must be constantly alert to the aberrations imposed upon our vision by conventions. Observe the arguments of competent and eminent scientists constructed to oppose such scientific novelties as evolution of species and relativity of physical phenomena, and behold the contrast between interbehaving with phenomena on the basis of established presuppositions and interbehaving without such hampering restrictions.

It is hardly necessary to enlarge upon this point when psychology is concerned. We need only refer to the persistence with which the dualistic tradition influences psychologists to extract their phenomena from the nervous sys-

[1] Cf., Kantor, J. R., An Outline of Social Psychology, Chicago, Follett, 1929.

[2] Schrödinger, E., Science and Human Temperament, N. Y., Norton, 1935.

tem. Traits and intelligence are regarded as manifestations of the organism's constitution rather than ways of interbehaving derived from former contacts with things. Mentality is a property of biological organisms which have only to mature to display their mental characteristics, etc.

Psychologists, of course, do not fail generally to accept an ideal of objectivity. It is interesting therefore to see how they attempt to avoid it if only verbally. Thus it is asserted that the relation of mental and physical is a philosophic not a scientific problem, but whether psychological phenomena really leave room for such a dualism is not questioned. Again, psychologists renounce any interest in systematic construction on the plea that sufficient unto the day are the laboratory data thereof, whatever they may amount to. Furthermore, we have the edifying declaration that the mental and the physical are really one. Sensations or mental qualities are neural impulses. Everything we find but the willingness to check the cultural influence of dualistic postulates by adhering rigidly to an interbehavioral principle.

INTERBEHAVIORAL OPERATIONS AND LINGUISTIC ABSTRACTIONISM

Since the sciences are all operational enterprises issuing from the same source and tending toward the same goal, vigilance over the operations exercised in one redounds to the benefit of all. Physics no less than psychology must constantly resist the lure of inherited tradition. The subjectivistic siren, whether in the guise of Machian sensations or mathematical abstractions, can be constantly observed leading physicists astray from concrete phenomena. Those physicists who in whatever form embrace sensations as the ultimate reality not only depart from the field which nourishes them, but also provide psychologists with grave temptation.

Though for the scientist, whether physicist or psychologist, nothing can be more fraught with danger than adherence to cultural tradition, he must be equally on guard against building his whole edifice upon particular kinds of investigation. In all probability these two tendencies are closely related. When the physicist allows himself only phenomena of high velocity or subatomic energy as building stones or when the psychologist erects his whole science on simple color discrimination we do not so much wonder that they build so badly as that they can build at all. Characteristic of our age is the appeal of inflated abstractions. Possibly the nth dimension of such abstractions appears in the linguism of the new positivism which asserts that the raw material of science is nothing more than a series of proposi-

tions. As Frank[1] puts it:

> In the exact sciences the intersubjective (universally intelligible) language consists of mathematical formulae from which observational propositions can be derived with the aid of laws of logic and prescriptions for measurement.

In short, a system is first developed in whole or part and then the world of nature is trimmed to its proportions. The only saving grace in this scheme is the agreement that the system has been derived from former contacts with concrete phenomena. But if we can resort to the saving grace, why not emphasize the previous interbehavior as a check in future operations?

In reviewing the treatises of Arne Fisher and John Maynard Keynes on *Probability*, Raymond Pearl has drawn a sharp contrast between the operational and the prescriptional attitude of scientists.

> On the one hand we have the point of view of the person who sees in the theory of probability one of the most potent tools the human mind has ever devised for penetrating deeper into the relations and laws of phenomenal nature. This is the point of view, in short, of the natural scientist who wishes to *use* the theory of probability in the conduct of the practical business of his life in the manner of approach of Laplace, Clerk Maxwell, Willard Gibbs, Karl Pearson and a host of the greatest figures in the history of science. On the other hand is the point of view of the person who regards the theory of probability as essentially only a branch of metaphysics, and finds its usefulness in the fact that it furnishes an entertaining and involved subject to speculate and talk about.[2]

Operationism interbehaviorally conceived we believe may serve as an antidote to this prescriptional and abstractional toxin.

[1] Frank, P., The mechanical vs. the mathematical correlation of nature, *Philosophy of Science*, 1937, 4, p. 57.
[2] *Science*, 1923, 58, p. 51.